Microdebris contamination in scleractinian coral in the Spermonde Archipelago, South Sulawesi, Indonesia

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Abstract. The Spermonde Archipelago has a high marine biodiversity and, at the same time, a high population on some islands. The anthropogenic influence of the mainland affects the surrounding environmental conditions, including the presence of microdebris in the coral reef ecosystem. In addition, microdebris contamination in scleractinian corals is still not widely known as an issue for this ecosystem. This study aimed to examine the presence of microdebris contamination on scleractinian corals in the Spermonde Islands. A sampling of scleractinian corals, including *Fungia fungites, Galaxea fascicularis, Porites cylindrica*, and the water column was carried out on four islands, representing four zones in the Spermonde Archipelago, including Kayangan (KY), Barrang Lompo (BL), Badi (BD), and Gondong Bali (GB). The samples were taken by hand picking, using SCUBA diving equipment at a depth of 5 to 7 m. Microdebris in the coral tissue and the water were extracted by adding 30% H_2O_2, then filtered by whatman cellulose disks with a diameter of 47 mm and the pore size of 0.45 μm, using a vacuum system. The particles were observed using a stereo microscope and then analyzed using FTIR (Fourier Transform InfraRed Spectroscopy) to determine the type of polymer. The abundance of microdebris in *F. fungites* ranged from 4.13±0.77 to 10.75±1.15 particles ind$^{-1.}$ In *G. fascicularis* it started from 5.50±0.96 to 11.38±1.31 particles colony^{-1}, and in *P. cylindrica* it ranged from 6.44±0.38 to 10.22±1.76 particles colony^{-1}. Furthermore, the number of particles in the water column was about 1.44±0.33 to 4.78±0.76 particles L^{-1}. The forms of microdebris found were fibers and fragments, consisting of four size classes. The most common polymeric materials found were paint and cotton. This research showed that the species of scleractinian corals and the water column were contaminated by microdebris in all zones. The highest contamination with microdebris was recorded near the closest island from the mainland and near the island with the highest population. Anthropogenic factors are thought to have an important impact on the presence of microdebris in the organisms and in the environment.
Key Words: *Fungia fungites*, *Galaxea fascicularis*, *Porites cylindrica*, FTIR, water column.

Introduction. Garbage disruption in the marine environment is getting more massive with changes in shape and size because it got fragmented over a long period. Fragmentation due to photodegradation, hydrolysis, thermal degradation, thermoxidative degradation, and biodegradation (Andrady 2011) produces particles <5 mm in size, known as microdebris, which originated from synthetic, semi-synthetic, or natural materials (Kroon et al 2018).

The most commonly reported are the synthetic microdebris called microplastics. Its small size, being easily carried by currents, it causes microdebris to be widespread and found in the environment such as the coast (Claessens et al 2011; Herrera et al 2018; Vidyasakar et al 2018), estuary and subtidal areas (Thompson et al 2004), mangrove ecosystems (Nor & Obbard 2014), reef ecosystems (Saliu et al 2018), sea level (Desforges et al 2014; Zobkov et al 2019) and deep-sea sediment (Van Cauwenberghe et al 2013). The presence of microdebris in these areas contaminates the food chain (Carbery et al 2018; Nelms et al 2018), because of their shape that resembles to a prey, which was evidenced by several organisms that have been contaminated with microdebris such as plankton (Cole et al 2013), gastropods, bivalves, and other filterfeeder molluscs (Li et al 2015; Davidson and Dudas 2016; Naji et al 2018; Teng et al 2019), and even commercial cephalopods such as squid and cuttlefish (Ilham et al 2021).

In 2021, Indonesia was listed as the fifth largest country contributing to the emission of plastic waste into the oceans from the top 20 countries (Meijer et al 2021). The condition allows a positive correlation with the number of microdebris. Like the previous global case, studies in recent years revealed that microplastics also have contaminated several marine ecosystems in several regions in Indonesia, from the surface to the water column (Cordova & Hernawan 2018; Syakti et al 2018; Cordova et al 2019), the sediments in coral reef areas (Cordova et al 2018) and even the deep sea (Cordova & Wahyudi 2016). Particularly in South Sulawesi, the researchers have conducted several studies, including environments like the estuary (Wicaksono et al 2020), the seagrass ecosystem, the surface of seawater, the sediments, as well as organisms such as bivalve, gastropod, echinoderm and fish, in Spermonde (Tahir et al 2019; Mawaddha et al 2020; Tahir et al 2020; Tanjung et al 2021).

The presence of microdebris in various ecosystems is closely related to the anthropogenic surroundings. The Spermonde Islands are a group of small islands located in the southwest of the island of Sulawesi and most of them are inhabited. The abundant diversity of marine life has made Spermonde waters an object of study since the early 20th century until now (Hoeksema 2012). In addition, these waters are also a provider of natural resources such as seafood for the people of the Makassar City, Maros Regency, Pangkep Regency and surrounding areas. So that, the existence of coral reef ecosystems in the Spermonde Islands is very important for scientific, social and economic aspects. However, this ecosystem faces a lot of pressure. The decline in environmental quality, due to global warming, illegal fishing using bombs, chemicals, and other anthropogenic activities, is also a factor affecting the coral cover in the Spermonde Islands (Ilham et al 2017). Therefore, the availability of data on the presence and level of microdebris contamination in coral reef ecosystems in Spermonde waters is very important.

Scleractinian or hard coral is one of the main supporting organisms in coral reef ecosystems. Based on research studies (Hall et al 2015; Allen et al 2017), synthetic microdebris or microplastics were found in the mesenterial tissue of coral. Then subsequent studies revealed the negative impacts that could be caused, such as endangering anti-stress capacity and the immune system (Tang et al 2018), overgrowth or anomalous growth, bleaching and even necrosis (Reichert et al 2018; Syakti et al 2019). However, the magnitude of the microdebris contamination in coral reef ecosystems and scleractinian corals at Spermonde is still unknown. Therefore, exploratory studies need to be carried out to (1) check the presence of microdebris contamination on scleractinian corals and in the waters of the Spermonde Islands, (2) to calculate the abundance of microdebris on the scleractinian coral and in the water column and their distribution, based on the observation of four zones in the Spermonde Islands, (3) to identify the characteristics of microdebris, based on the shape, size (size class) and type of the polymer/source. Testing the polymeric materials using a FTIR (Fourier Transform Infra-Red) microscope is very important because the microdebris consist not only microplastics (synthetic particles), but also other particles derived from semi-synthetic and natural materials (Kroon et al 2018) such as clothing fibers, ship paint flakes, and others.

Material and Methods

Description of the study sites. Sampling was carried out in June-August 2019 on several islands in the Spermonde Archipelago, including Kayangan (KY), Barrang Lompo (BL), Badi (BD), and Gondong Bali (GB) (Figure 1). The islands were selected based on the division of the zones, consisting of the Inner zone (Zone I), Middle inner zone (Zone II), Middle outer zone (Zone III), and Outer zone (Zone IV) (Hoeksema 2012). Kayangan Island is a tourist attraction and is uninhabited, while the other three islands are populated, the fishing being the dominant occupation.

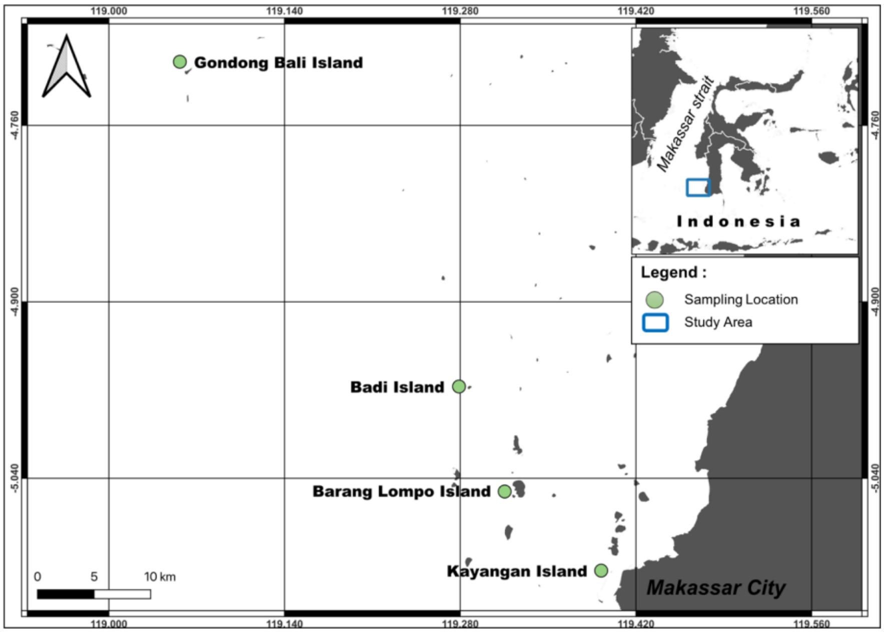

Figure 1. The sampling sites on the Spermonde archipelago.

Sampling of coral and water column. Three coral species were selected as the object of study, i.e. *Fungia fungites* Linnaeus, 1758, *Galaxea fascicularis* Linnaeus, 1767, and *Porites cylindrica* Dana, 1846. The three species were selected based on their distribution and were commonly found in research sites from zone I to zone IV of Spermonde and in the Indo-Pacific region. In addition, the three species also represent corals with large, medium, and smallest polyp sizes.

Sampling was executed at a depth of 5 to 7 m with SCUBA diving equipment. The total number of scleractinian corals used in this study was 96 specimens, i.e. 32 individuals of *F. fungites*, 32 colonies of *G. fascicularis*, and 32 colonies of *P. cylindrica* taken from all the islands. The diameter of *F. fungites* ranged from 10-12 cm, and as colonizing scleractinian corals, the specimens of *G. fascicularis* and *P. cylindrica* were selected only in small colonies or even among coral fragments, so that the sampling was not destructive (Figure 2).

Figure 2. Morphology of species (a) *Fungia fungites*, (b) *Galaxea fascicularis* and (c) *Porites cylindrica* (original photos).

A single colony of *G. fascicularis* consisted of 30-50 polyps. *P. cylindrica* consisted of 400-500 polyps with a length of ±5 cm. In addition, water column from each island was also collected to reveal the effect of the island's distance from the mainland on the microdebris contamination. 10 L of water were taken using a water sampler and then filtered using a 60 μm mesh to obtain 100 mL of filtered water.

Microdebris extraction. Microdebris extraction of scleractinian coral was conducted by separating coral tissue from corallite using the airbrush method (Hankins et al 2018; Johannes & Wiebe 1970). The spray gun is directed directly at coral polyps at a distance of ±5 cm. *F. fungites* was extracted individually as solitary coral, while the extraction at *G. fascicularis* was carried out by shooting water into individual polyps in turns, until 30 polyps were extracted. The same procedure was performed on *P. cylindrica* which has a polyp size of about 1 mm. Therefore, by extracting approximately ±2 cm of colony length, it was estimated to consist of 100-150 individual polyps. Coral tissue was collected in a glass bottle using a metal funnel.

The coral tissue solution was added with 50-70 mL H_2O_2 30% (adjusted to the sample volume), then homogenized with a hot plate magnetic stirrer at 1,000 rpm/60°C for ±4 hours. The solution was filtered using a 60 µm mesh to separate the particles of microdebris from the impurities. Furthermore, the mesh holding the particles was rinsed with sterile distilled water and collected in a beaker to be filtered using Whatman cellulose filter paper (diameter 47 mm, pore size 0.45 µm).

Microdebris in the water column was extracted by adding 50 mL H_2O_2 30% into 100 mL of filtered samples for removing biological matter. The sample was homogenized using a hot plate magnetic stirrer on 300 rpm/60°C for ±1 hour. Subsequently, the solution was filtered using a vacuum method with Whatman cellulose filter paper (diameter 47 mm, pore size 0.45 µm).

Visual observation and identification*.* The particle of microdebris was observed using a stereo microscope in order to be recorded and counted, then divided according to their shape and size (1,000–5,000 µm; 1,000-500 µm, 500–100 µm and 100–60 µm). The particle criteria observed refers to the following characteristics (Nor & Obbard 2014; Nelms et al 2018; Hidalgo-Ruz et al 2012): (1) the particle size is less than 5 mm, (2) it has no cellular structure, (3) homogeneous or non-glossy color, (4) unbranched and segmented particle fibers. Several particles were selected as representatives of the samples then analyzed using an FTIR microscope with spectra data recorded by 128 scans in the spectral range of 650-4,000 cm^{-1} at a resolution of 8 cm^{-1} (Song et al 2015) and the aperture adjusted to the smallest particle size.

Statistical analysis*.* One-way ANOVA was used to compare the abundance of microdebris in each species from different islands. The abundance of microdebris among the three species was not compared because the number of polyps extracted was not equal. Data were analyzed using software R 4.0.3. (R Core Team 2019).

Results

The abundance of microdebris in coral species and water column. Three coral species inclluding *F. fungites, G. fascicularis* and *P. cylindrica* in four islands were contaminated by microdebris with various number of particles (Figure 3). A significant difference ($p<0.05$), based on the one-way Anova, was indicated by the difference in the assigned letters. The abundance of microdebris found in each specimen and in the water column was determined: for *F. fungites*: in KY (10.75 ± 1.15), BL (10.50 ± 1.12), BD (8.13 ± 1.04) and GB (4.13 ± 0.77) particles individual^{-1}; *G. fascicularis*: KY (5.50 ± 0.96), BL (11.38 ± 1.31), BD (8.13 ± 1.04) and GB (7.50 ± 0.89) particle colony^{-1}; *P. cylindrica*: KY (6.60 ± 0.51), BL (10.22 ± 1.76), BD (6.44 ± 0.38) and GB (9.44 ± 1.12) particle colony^{-1}, and water column: KY (4.78 ± 0.76), BL (4.04 ± 0.41), BD (4.3 ± 1.75) and GB (1.44 ± 0.33) particle L^{-1}.

F. fungites from GB contained the lowest microdebris contamination. The mean of microdebris numbers in *F. fungites* from GB showed significant differences ($p<0.05$), compared with the microdebris numbers in *F. fungites* from KY, BL, and BD. *G. fascicularis* from BL contained the highest microdebris concentration and showed significant differences ($p<0.05$) with the microdebris concentration in *G. fascicularis* from KY. There was no significant difference between the mean number of microdebris in *P. cylindrica* from each island. Microdebris abundance in the water column showed a pattern that was almost similar to the microdebris abundance in *F. fungites* from Kayangan Island, the area with the highest contamination level, while GB had the lowest contamination level.

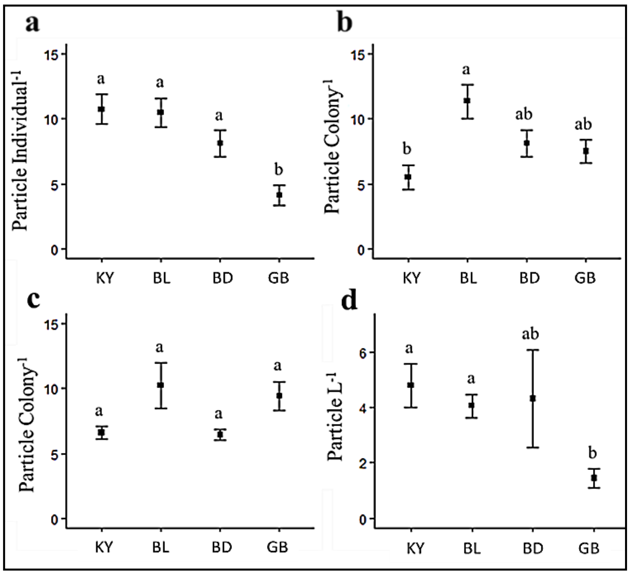

Figure 2. The abundance of microdebris in a. *Fungia fungites*, b. *Galaxea fascicularis*, c. *Porites cylindrica* and d. water column.

The mean of microdebris numbers in GB was significantly different from microdebris numbers in KY and BD. The level of contamination of all specimens indicated that KY and BL islands had a significant anthropogenic impact compared to BD and GB islands.

Percentage of form and size class of microdebris. Based on the percentage, the fiber is the dominant form found in all species, while fragments are more commonly found in the water column except in GB island (Figure 4), although, incidentally, there were sites with a higher percentage of fragments than fiber in each species, including *F. fungites* in KY, *G. fascicularis* in BD, then *P. cylindrica* in BL and GB.

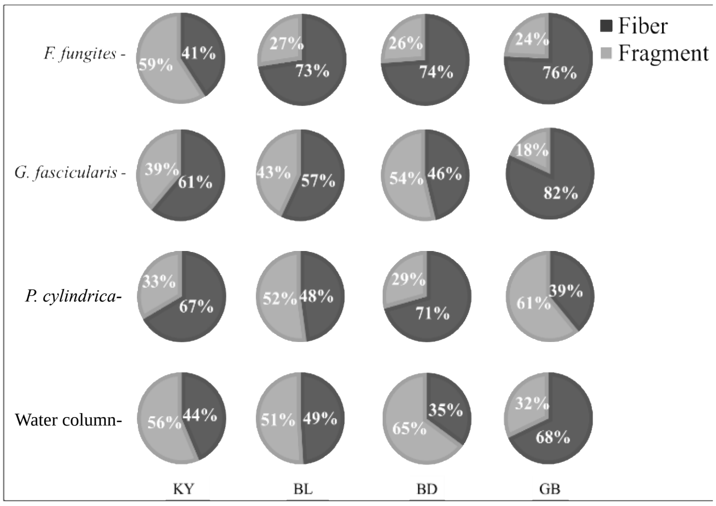

Figure 3. Comparison of the percentage of microdebris forms found in the coral species and water column.

The most common size class of microdebris found in this study ranged from 100 µm-60 µm and 500 µm-100 µm (Table 1). The size class with the lowest percentage in each specimen seemed random. In *F. fungites*, the lowest percentage of particles by size was observed aș follows: 5.000-1.000 µm and 1.000-500 µm on KY, 1,000-500 µm on BL, then 100-60 µm on BD and GB. *G. fascicularis* and the water column have a similar pattern, where the size class with the lowest percentage was 5000 µm-1000 µm on all islands except for GB, whose lowest size class ranges from 100 µm-60 µm. Furthermore, the size class with the lowest percentage in *P. cylindrica* from KY and GB was found at

5,000 μm-1,000 μm, from BL at 1,000-500 μm, and from BD at 100-60 μm. This study shows that the largest fibers and fragments can be ingested by corals with small polyps.

Table 1

Percentage of microdebris size class found in scleractinian coral and water column

Specimen	*Site code*	*Size class %*			
		5,000-1,000 μm	*1,000-500 μm*	*500-100 μm*	*100-60 μm*
F. fungites	KY	13.95	13.95	24.42	47.67
	BL	28.57	15.48	29.76	26.19
	BD	30.77	21.54	32.31	15.38
	GB	30.30	24.24	42.42	3.03
G. fascicularis	KY	11.36	29.55	29.55	29.55
	BL	13.19	16.48	35.16	35.16
	BD	9.23	18.46	27.69	44.62
	GB	21.67	30.00	43.33	5.00
P. cylindrica	KY	15.15	24.24	27.27	33.33
	BL	13.04	11.96	33.70	41.30
	BD	25.86	27.59	29.31	17.24
	GB	10.59	16.47	30.59	42.35
Water column	KY	14.64	14.64	33.89	36.82
	BL	12.38	19.80	29.21	38.61
	BD	9.30	10.70	30.70	49.30
	GB	33.33	25.00	23.61	18.06

Identification of microdebris using the stereo microscope and the FT-IR microscope. Based on observations with a stereo microscope, twenty-eight particle types could be identified by FT-IR. The FT-IR examination showed that the processed particles were identified as paint, polyethylene (PE), rayon, cotton, and wool based on the FT-IR microscope instrument library (Table 2).

Table 2

Particle types identified using the FT-IR microscope

Polymer type	*Number of particles*	*Percentage (%)*	*Form*	*Sample codes*
Marine paint*	14	50.00	Fragment	FU BL1, FU KY3, GA BD5, GA BD5, GA BL1, GA BL2, GA GB 1, PO BD2, PO BL1, PO BL1, PO GB 1, PO GB2, PO KY1, PO KY1
Cotton	8	32.14	Fiber	FU BL1, FU GB7, FU KY3, GA BL1, GA BL2, GA KY8, PO BD2, PO KY1
Rayon	2	7.14	Fiber	FU BL1, FU KY3
Wool	1	3.57	Fiber	PO KY9
Unsaturated Polyester Resin	1	3.57	Fragment	PO BL1
Polyethylene	1	3.57	Fragment	GA GB1
Synthetic leather*	1	3.57	Fragment	PO GB1

FU - *F. fungites,* GA - *G. fascicularis,* PO - *P. cylindrica,* * identified particles only based on the FTIR microscope.

Furthermore, the characteristics of each peak spectra were identified manually by comparing them with the spectra that have been identified from previous studies. For example, the peak characteristic of PE (Figure 5b) can be observed at wave numbers 2918, 2851, 1465, and 719 cm^{-1}. This peak shows the same character as the PE present in the study (Rajandas et al 2012).

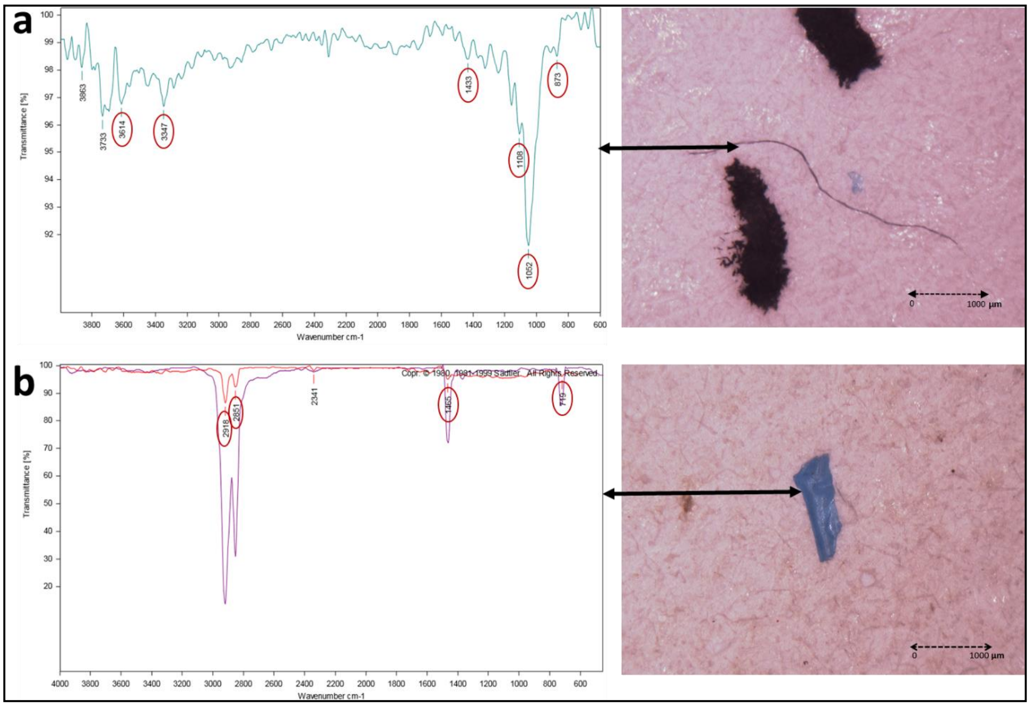

Figure 4. The FT-IR spectra of a. Black fiber of cotton, b. Blue fragment of polyethylene.

Discussion. Microdebris contamination on *F. fungites*, as the largest polyp coral, appears to have a pattern similar to microdebris contamination in the water column. The number of microdebris in the water column shows that KB is the location with the lowest contamination compared to other islands. Based on BPS (2020a;2020b) data, the number of residents in the urban village area covering each island, including Barrang Lompo (4,783 individuals), Mattiro Deceng district including Badi Island (3,184 individuals), and Mattiro Ujung district, including Gondong Bali Island (1,560 individuals) were obtained. It is suspected that residential anthropogenic activities play a role in the existence of microdebris on each island. On the other hand, the presence of microdebris in the Spermonde archipelago also received supplies from the mainland, as evidenced by the presence of microdebris on the uninhabited island of KY. This supports previous research in Bintan water, where the highest microplastic concentrations were found at sites affected by urban areas. Syakti et al (2018) and Cordova et al (2019) also reported that the highest abundance of microplastics was found at stations close to land and the lowest was found at the farthest stations in the northern coastal waters of Surabaya, Indonesia.

The microdebris contamination in *G. fascicularis* and *P. cylindrica* looked more volatile. Reichert et al (2018) showed that each coral has a different response to the microplastic particle exposure. In a feeding trial, corals retain microdebris indifferent numbers during the experiment (Allen et al 2017; Hankins et al 2018). *Astrangia poculata* retained ~8% of the ingested plastic for 24h or more (Allen et al 2017). *Orbicella faveolata*, a small polyp coral, show more retaining particles than *Montastraea cavernosa*, a large polyp coral (Hankins et al 2018). It may also occur in our specimens such as *F. fungites*, a large polyp coral, *G. fascicularis*, a medium polyp coral, and *P. cylindrica* a small polyp coral. The retained microdebris were localized deep within the polyp and were wrapped by mesenterial tissue, being difficult to remove from the polyp (Hall et al 2015), so the accumulated microdebris could interfere with the number of microdebris extracted from polyps due to the experimental treatment.

Accumulated microdebris also harm the scleractinian corals in natural ecosystems. Experimental studies have proven that microdebris exposure, such as microplastics, affects coral health, then causes bleaching and necrosis in coral tissue (Reichert et al 2018; Syakti et al 2019). However, the number of extracted particles from the water column and the coral specimens in this study was considerably lower than the particle concentration (e.g. 4,000 particles L^{-1}) found in experimental designs (Reichert et al 2018). Therefore, future exploration research is needed.

Hankins et al (2018) found no significant difference between the number of microbead and microfiber ingested by *M. cavernosa* and *O. faveolata.* Although coral species might have different types of polyp sizes, they have no preference for ingesting fiber and fragments. Therefore, *F. fungites, G. fascicularis*, and *P. cylindrica* showed inconsistent percentage patterns of fiber and fragment. In addition, the cause of chemoreceptor-induced ingestion of microdebris particles in corals remained unclear (Allen et al 2017). So that, what drives the ingestion of different numbers of fiber particles and fragments in this study is still unknown.

The microdebris size class of 5,000-1,000 μm contaminated corals with all types of polyps (large, medium and small), in this study. According to Hankins et al (2018), corals can ingest 3-5 mm microfiber as easily as microbeads <1mm, showing similar responses as the fiber and fragments from the current study, where corals with medium and small polyps were also contaminated with microdebris of the largest class size.

The fragments generally found were paint (50%) of the total selected particles. One of the fragments was identified as PE. Hall et al (2015) also revealed that the fragments found in the Great Barrier Reef area generally come from marine paint and fishing floats. In our findings, unsaturated polyester resin was found, which is used as a gel coating for fiber composites such as the body of boats. In addition, based on the type of polymer, cotton was the common fiber found (32.14%) and supposedly originates from domestic laundries (Browne et al 2011; Hartline et al 2016; Napper & Thompson 2016; Pirc et al 2016; De Falco et al 2018; Jönsson et al 2018), in the Spermonde area along with mainland (Makassar), which is one of the major cities in Indonesia. According to our findings that classified the particles based on the type of polymer, this research could inform that microdebris are not only microplastics or sintetic particle, but also non-plastic items such as natural and semi-synthetic particle. Therefore, further research is expected to be supported by a method that can identify the polymer of each particle found, so that non-plastic particles will not be reported as plastic anymore.

Conclusions. This study shows that the three species of scleractinian corals, namely *F. fungites, G. fascicularis, P. cylindrica*, and the water column are contaminated by microdebris. Microplastic contamination was found in all zones, from the closest to the furthest from the mainland, with an abundance ranging from 1.44±0.33 to 11.38±1.31 particles per specimen. The forms of microdebris found were fibers and fragments consisting of four size classes, and the most common polymeric materials found were paint and cotton.

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Conflict of interest. The authors declare no conflict of interest.

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